# DIE EJECTOR SYSTEM USING LINEAR MOTOR

## Field of the Invention

The invention relates to a mechanized system for the removal of a bare semiconductor chip or die from an adhesive film on which it is mounted, and in particular to a device for inducing partial delamination of a die from the adhesive film prior to total removal of the die.

## Background and Prior Art

During a semiconductor packaging process, a plurality of interconnected individual bare semiconductor chips or dice comprised in a wafer are often mounted onto an adhesive film stretched out on a wafer ring for singulation to separate the dice from one another. Mylar film is commonly used as the film with an adhesive surface for mounting the wafer. After singulation, the dice are individually picked up from the adhesive film and placed onto another die, a leadframe, laminate substrate or other carrier depending on the application. For automatically picking up the dice, a die ejection system is used to facilitate effective removal of the dice. In order to avoid the risk of die crack, partial delamination of the die from the adhesive film is advantageous before total removal of the die by a pick-head. The die ejection system thus has die ejector pins to lift a die from an opposite side of the adhesive film from its mounting side to partially delaminate the die from the adhesive film, and thereafter, a pick-head to remove the die totally from the adhesive surface.

Traditionally, die bonding machines use die ejection systems based on some kind of transmission/linkage mechanism used to convert rotational motion of a rotary motor into translational motion used for facilitating ejection of a die. For example, US patent number 5,755,373 for a "Die Push-Up Device" discloses a mechanism including a push-up needle raised and lowered by a cam that is actuated by a rotary motor.

Figure 1 is a simplified diagram showing various parts of a conventional ejection system in greater detail. The ejection pins **1** are held by a collet **1a**, which is mounted at the end of a shaft **2**. A roller **15** is affixed to the lower end of the shaft. A rotary motor **20** is used to drive a high precision cam **16**, which actuates the shaft **2** through the roller **15** in order to reduce friction. Typically a step-down transmission consisting of a timing belt **18** and pulleys **17, 19** is used to drive the cam **16**. Any other suitable transmission mechanism may be used.

Figure 2 shows the typical operation of ejector pins used to induce partial delamination of dice mounted on an adhesive Mylar sheet. As shown in Figure 2a, the ejector pins **1** are normally positioned just under a plurality of dice 22 that have been mounted on an adhesive surface of the Mylar sheet **21**. This is to allow a wafer table holding the Mylar sheet **21** to execute free indexing motion in the horizontal plane without any obstruction from the pins **1**. After the wafer table executes an indexing motion so as to position a die at the pick position on the ejector platform **23**, the ejector pins **1** move up as shown in Figure 2b and at the same time, vacuum force **24** in the direction indicated by dotted arrows is applied from below the Mylar sheet **21**. The ejector pins **1** contact the Mylar sheet **21** and lift the die **22** along with the sheet. However, strong vacuum applied from below serves to keep some areas of the Mylar sheet **21** in close contact with the top surface of the ejector platform **23**. A rubber seal **25** is provided to concentrate the vacuum around the area of the pick-up position.

In relation to the conventional die ejector system described above, the presence of several components between the drive motor **20** and the end-effector i.e. ejector pin array **1** introduces substantial compliance (reciprocal of stiffness), friction, backlash and hysteresis problems in the system. This reduces the control bandwidth thus severely limits the performance of the ejector system. Secondly, it is difficult to control the impact of the pins on the die during ejection. This could lead to cracking of the die, more so as ever-thinner dies are being introduced into use in the semiconductor industry.

Therefore, it would be desirable to implement a directly driven ejector mechanism for better control of the motion of the ejector pins **1**. Moreover, it would also be useful to have a flexure bearing design associated with the directly driven ejector mechanism to improve accuracy and repeatability of the motion.

Summary of the Invention

It is thus an object of the present invention is to provide an improved die ejector system that avoids some of the aforesaid problems associated with the prior art.

According to a first aspect of the invention, there is provided a die ejector system for removing a die from an adhesive surface, comprising: an ejector tool that is operative to move relative to the die whereby to push the die; a shaft for holding the ejector tool; a linear motor comprising a forcer and a stator, wherein the forcer is coupled to the shaft and is movable relative to the stator; and a die pick-up device for removal of the die from the adhesive surface after the die is pushed by the ejector tool.

According to a second aspect of the invention, there is provided a method for removing a die from an adhesive surface, comprising the steps of: providing an ejector tool that is movable relative to the die; mounting the ejector tool onto a shaft; coupling the shaft to a forcer of a linear motor that is movable relative to a stator of the linear motor; moving the forcer relative to the stator whereby to push the ejector tool against the die; then removing the die from the adhesive surface.

It would be convenient hereinafter to describe the invention in greater detail by reference to the accompanying drawings which illustrate one embodiment of the invention. The particularity of the drawings and the related description is not to be understood as superseding the generality of the broad identification of the invention as defined by the claims.

Brief Description of the Drawings

An apparatus and method in accordance with the invention will now be described with reference to the accompanying drawings, which is shown solely by way of a non-limiting demonstrative example of the present invention, in which:

FIG. 1 shows an example of a prior art ejection system wherein a cam-operated ejector system is employed;

FIG. 2 shows the typical operation of ejector pins used in the partial delamination of a die from a sheet of adhesive film;

FIG. 3 shows a cross-sectional side view of a preferred embodiment of a die ejector device according to the preferred embodiment of the invention;

FIGS. 4a and 4b show side and plan views respectively of a flexure stack, whilst FIGS. 4c to 4e show respectively a flexure, a rim spacer and a central spacer comprised in the flexure stack; and

FIG. 5 shows three designs of flexures with polar symmetry.

Detailed Description of the Preferred Embodiment

The preferred embodiment of the present invention will now be described with reference to the drawings. FIG. 3 shows a cross-sectional side view of the preferred embodiment of a die ejector device according to the invention. The mechanism of the ejector device is intended to achieve straight-line motion of an ejection tool relative to a die whereby to push the die. The moving part of the mechanism is actuated by a voice coil motor in such a way that the effective actuating force is co-axial with a shaft bearing the ejection tool.

The ejector tool comprising a pin array **1** and collet holder **1a** is thus affixed and held at an end of a top shaft **2a.** Preferably, a force sensor **14** is

sandwiched between the top shaft **2a** and a bottom shaft **2b** for detecting a force exerted by the pin array **1**. The bottom shaft **2b,** is suspended from a main support **4,** using flexure bearings, which may be in the form of flexure stacks **3** comprising flat circular flexure discs, coupled to the bottom shaft **2b**. Normally, two sets of flexure stacks **3** separated by a suitable distance are used on the die ejector device. It is also preferable that the two flexure stacks **3** are positioned on opposite sides of the linear motor.

The flexure stacks **3** are spaced apart by a spacer tube **12** and a coil mount **8** of the voice coil **9** in a moving section, and by the main support **4** in a stationary section. An optical encoder **7** including a moving encoder scale **7b** is then assembled on the bottom shaft **2a** using a scale mount **7c**. The whole moving sub-assembly is then clamped tight using a nut **10**. A position sensor, for example a stationary encoder read-head **7a**, is then aligned appropriately with the encoder scale **7b** and coupled to it. Any other type of position sensor, such as a capacitive, inductive or other sensor may be suitably used in place of the optical encoder **7**.

A stator of the linear motor, such as radially-magnetized permanent magnets **11**, are attached around an inside surface of the main housing **4**, such as by using glue. The permanent magnets **11** are preferably made of a high energy density material such as Neodymium Ferrous Boron. With this set-up, a radial magnetic field is created in an annular air gap **13** between the permanent magnets **11** and an inner section **4a** of the main housing **4**. An axial force is induced on a movable forcer, such as a coil **9** that is adapted to carry a current, when it is appropriately positioned in the magnetic air gap **13** and is energized by an electrical current. When the direction of the current is reversed, the force on the coil **9** is also reversed. The above-described voice coil motor is thus used to directly drive and move the ejector pin array **1**. Alternative topologies of a voice coil motor or a multiphase linear motor may be used in place of the voice coil motor described above. Furthermore, using an alternative construction, the movable forcer may comprise permanent magnets whereas the stator may comprise coils adapted to carry current.

The force sensor **14** directly senses the force exerted by the pins **1** on the bottom side of the Mylar sheet **21**. The signal from the force sensor **14** may be used to minimize the impact of the pins on the die and also to exert a controlled amount of ejection force as required to partially delaminate a die. Once the die has been sufficiently delaminated to facilitate removal, a die pick-up device (not shown) may hold onto and remove the die from the adhesive surface of the Mylar sheet **21**.

FIGS. 4a and 4b show side and plan views respectively of a flexure stack **3**. FIGS. 4c to 4e show respectively a flexure 3a, a rim spacer 5 and a central spacer 6 comprised in the flexure stack **3**. Each flexure stack **3,** comprises one or more flexure discs or flexures **3a**, interspersed with spacers in the form of rim spacers **5** and central spacers **6**. Each rim spacer **5** is so shaped as to be positionable adjacent to and cover that part of the flexure **3a** that is meant to be stationary. It has holes **5a**, which are used to mount the flexure stack **3** on the main housing **4**. Each central spacer **6** has a hole **6a** which mates with the bottom shaft **2b** for facilitating mounting thereto. The central spacer **6** is so shaped as to be positionable adjacent to and cover portions of the flexure **3a** that move relative to the aforementioned part of the flexure **3a** that is meant to be stationary, but do not flex. Flex-arms **3b** of the flexure disc **3a** are not covered by any of the spacers **5, 6** and can flex to yield the desired axial motion between the portions that move and the parts that are stationary. The mutual coupling of the flex-arms **3b** within a flexure **3a**, and also within different flexures **3a** in the flexure stack **3**, imparts a very high radial stiffness to the entire suspended assembly, while keeping the axial stiffness of the flexure stack **3** relatively low.

Flexures **3a** are especially suitable for guiding movement of the ejector pins **1** due to the excellent inherent repeatability and smoothness of their motion trajectory while avoiding friction and wear that are associated with conventional bearings. Some typical flexure designs are shown in FIG. 5. The flexure designs may be in the form of flat discs that are fractions of a millimeter thick. Each disc has a specified number of slots (usually but not always, three), and can have spiral, straight or arc shapes or a combination

thereof. They are preferably regularly-shaped and machined using either wire Electro-Discharge Machining, photo-lithography or any other suitable method for yielding a number of flexing "arms" which bear the load of a moving member. Very high ratios of radial stiffness to axial stiffness can be realized using such flexures.

Flexures with polar symmetry such as those shown in Fig. 5 suffer from a small parasitic rotation about the motion axis. Such flexures have been used in long life compressors and cryogenic coolers, for example, as disclosed in US patent number 5,351,490. Since even such a small parasitic rotation cannot be tolerated in the present application, it is preferable to design and use flexures without any parasitic motion whatsoever. The preferred embodiment of a flexure disc shown in Fig. 4 is free of a net parasitic motion.

Actuation of the die ejector mechanism using flexures of circular symmetry is preferably implemented by incorporating a brushless linear motor using permanent magnets. The linear motor could be either of single phase (commonly called a voice coil motor) or of multiphase design, in any of the several possible topologies but most are usually cylindrical. In order to make best use of the available space to obtain a compact design, the cylindrical voice coil motor keeps the actuating force or pushing force virtually aligned with the axis of the flexure discs along which the flexure discs are adapted to flex. The position sensor provides position feedback enabling the motor to be operated in closed loop servo mode for very precise control over the axial position of the ejector pin array mounted on the moving shaft.

The invention described herein is susceptible to variations, modifications and/or additions other than those specifically described and it is to be understood that the invention includes all such variations, modifications and/or additions which fall within the spirit and scope of the above description.